Inter (Part-I) 2019

Physics	Group-I	PAPER: I
Time: 2.40 Hours	(SUBJECTIVE TYPE)	Marks: 68

SECTION-I

2. Write short answers to any EIGHT (8) questions: (16)

(i) Write down the two uses of dimensional analysis.

Ans Following are the two uses of dimensional analysis:

1. We can check the correctness of a given formula or an equation and can also derive it.
2. Dimensional analysis makes use of the fact that expression of the dimensions can be manipulated as algebraic quantities.

(ii) What are the characteristics of an ideal standard?

Ans An ideal standard has two principal characteristics:

It is accessible and it is invariable. These two requirements are often incompatible and a compromise has to be made between them.

(iii) If $\vec{A} = 4\hat{i} - 4\hat{j}$, what is the orientation of $\vec{A}$?

Ans We know that $\vec{A} = Ax\hat{i} + 4y\hat{j}$

$$|\vec{A}| = \sqrt{(4)^2 + (-4)^2}$$
$$= \sqrt{16 + 16} = \sqrt{32} = 4\sqrt{2}$$

$$\vec{A} = \frac{\vec{A}}{|A|} = \frac{4i - 4j}{4\sqrt{2}}$$
$$= \frac{4i}{4\sqrt{2}} - \frac{4j}{4\sqrt{2}}$$
$$= \frac{i}{\sqrt{2}} - \frac{j}{\sqrt{2}}$$

(iv) Define resultant vector and component of a vector.

Ans A vector which is the sum of two or more than two vectors and whose effect is the same as the combined effect of all the vectors to be added is called the resultant vector of all those vectors.

Two or more than two vectors which when added give us a single resultant vector, are called components of that resultant vector.

(v) The magnitude of the sum of two vectors is zero. What are the conditions to get this?

Ans If $\vec{A} + \vec{B} = 0$, then we can write

$$\vec{A} = -\vec{B}$$

We can write in terms of their rectangular components:

$$A_x \hat{i} + A_y \hat{j} = -(B_x \hat{i} + B_y \hat{j})$$
$$= -B_x \hat{i} - B_y \hat{j}$$

By comparing the coefficients of $\hat{i}$ and $\hat{j}$, we get

$$A_x = -B_x$$
$$A_y = -B_y$$

It means that if sum of the two vectors is zero, then their respective rectangular components will be of the same magnitude but in opposite direction.

(vi) A car is moving along a circle of radius r. It completes four revolutions and terminates its journey at starting point. How much work is done by the car? Explain.

Ans A car is moving along a circle of radius r. It completes four revolutions and terminates its journey at starting point. So, its displacement is zero. Hence, the network done is also zero.

(vii) How energy is obtained by water waves and what is the source of this energy?

Ans The tidal movement and the winds blowing across the surface of the ocean produce strong water waves. Their energy can be utilized to generate electricity. A method of harnessing wave energy is to use large floats which move up and down with the waves.

(viii) Explain the term systolic and diastolic pressure.

Ans Pressure of the blood in human body for its circulation is always greater than atmospheric pressure. There are two limits of pressure. Lower limit is known as diastolic pressure. It varies for normal human body from 75 torr to 80 torr. Upper limit of the pressure is known as systolic pressure and its value is 120 torr for normal and healthy human body.

where $1 \text{ torr} = 133.3 \text{ Nm}^{-2}$

At systolic pressure, the flow of blood is turbulent.

At diastolic pressure, the flow of blood is streamline.

(ix) Two row boats moving parallel in the water are pulled towards each other. Explain, why?

Ans When two boats are moving parallel to each other in the same direction, then velocity of water between them (which is dragged with the boats) will be large. According to Bernoulli's equation, when velocity of fluid is large, pressure is low.

(x) Is any relation existed between damping and resonance? Explain.

Ans In case of resonance, the amplitude of vibration becomes very large when damping is small. Thus, presence of damping prevents the amplitude from becoming sufficient large. The amplitude decreases rapidly at a frequency slightly different from resonance frequency.

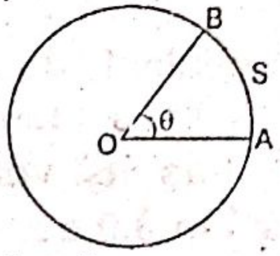
(xi) In relation to SHM, explain the equation $y = A \sin(\omega t + \phi)$.

Ans On this equation, y is the instantaneous displacement of a particle executing S.H.M with amplitude A. Here ϕ is initial phase angle. ωt is angle subtended in

2. Weather forecast
3. Navigation
4. Defense and other military purpose
5. Mobile phone signals
6. Broadcasting television program

(vi) Show that $S = r\theta$ where S = Arc length, r = radius of the circle, θ = angle in radian.

Ans Consider a circle of radius "r". Let "S" be an arc length of this circle connecting the points A and B as shown in figure below.



By the definition of radian, we can understand that

$$1 \text{ radian} \propto r \Rightarrow 1 \text{ radian} = kr \qquad \text{(i)}$$

and $$\theta \text{ radian} \propto s \Rightarrow \theta \text{ radian} = ks \qquad \text{(ii)}$$

where k is constant of proportionality by dividing eq. (ii) by eq. (i), we get,

$$\frac{\theta \text{ radian}}{1 \text{ radian}} = \frac{ks}{kr}$$

$$\frac{\theta}{1} = \frac{s}{r}$$

$$s = r\theta$$

(vii) What do you mean INTELSAT VI? What are the frequencies on which it operates?

Ans The largest telecommunication satellite system is managed by 126 countries, International Telecommunication Satellite Organization (INTELSAT). It operates at microwave frequencies of 4, 6, 11 and 14 GHz and has a capacity of 30,000 two-way telephone circuits plus three T.V channels.

(viii) A disc without slipping rolls down a hill of height 10.0 m. If the disc starts from rest at the top of the hill, what is the speed at the bottom?

Ans $h = 10\text{ m}$

$g = 9.8$

$$V = \sqrt{\frac{4gh}{3}}$$

$$V = \sqrt{\frac{4 \times 9.80 \times 10}{3}} = 11.4 \text{ ms}^{-1}$$

(ix) How the speed of sound change with the density of the medium?

Ans At the same temperature and pressure for the gases having the same value of γ, the speed is inversely proportional to the square root of their densities $\left(v = \frac{\gamma p}{\rho}\right)$.

Thus, the speed of sound in hydrogen is four times its speed in oxygen as density of oxygen is 16 times that of hydrogen.

(x) A pipe has a length of 1 m. Determine the frequencies of the fundamental, if the pipe is open at both ends. Speed of sound = 340 ms^{-1}.

Ans

$$f_1 = \frac{nv}{2l} = \frac{1 \times 340}{2 \times 1} = \frac{340}{3} = 170 \text{ s}^{-1} = 170 \text{ Hz}$$

$$f_2 = 2f_1 = 2 \times 170 = 340 \text{ Hz}$$

$$f_3 = 3f_1 = 3 \times 170 = 510 \text{ Hz}$$

(xi) State Doppler Effect. Write down its one application.

Ans The apparent change in the pitch of a wave cause by the relative motion of either source of waves or the observer / listener, is called Doppler effect.

Example:

Bat navigates and finds food by echo (reflected wave) location (Doppler effect). It ends ultrasonic waves and then receives them.

(xii) How Doppler effect can be used to monitor blood flow?

Ans The Doppler effect can be used to monitor blood flow through major arteries. Ultrasound waves of frequencies 5 MHz to 10 MHz are directed towards the artery and a receiver detects the back scattered signal. The apparent frequency depends on the velocity of flow of the blood.

4. **Write short answers to any SIX (6) questions: (12)**

(i) What is Bragg's law? Derive Bragg's equation.

Ans In 1914, W.H. Bragg and W.L. Bragg studied the atomic structure of crystals by using X-rays. They founded that a monochromatic beam of X-rays as reflected from a crystal plane as if it acted like a mirror, to understand this effect, a series of atomic planes, of constant interplaner spacing "d" parallel to crystal face by lines PP_1' P_1P_1' P_2P_2'.

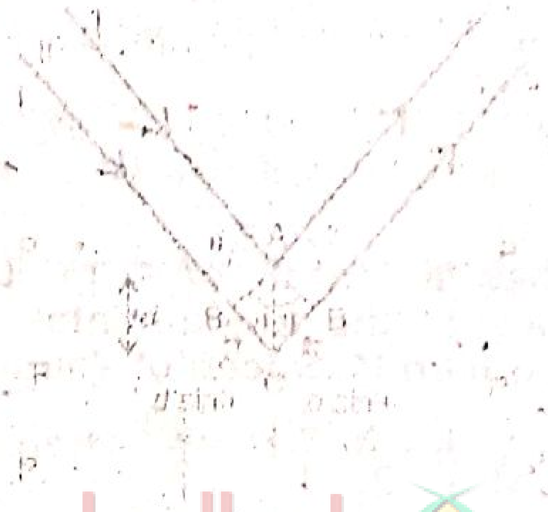


Fig. Diffraction of X-rays from the lattice planes of crystal.

Bragg's Equation:

Suppose a beam of X-ray incident at an angle θ on one of the plane of crystal in fig. Consider the beam-I and beam-II are reflected from upper and lower planes of atom. Let "d" is the distance between the two planes. It is evident from the fig. that beam-II cover more distance than beam-I.

Thus, the distance (BC + B′C) is the effective path difference between two beams *i.e.*,

$$\text{Path difference} = (BC + B'C) \qquad (1)$$

From right-angled triangle ABC, we have

$$\frac{BC}{d} = \sin\theta$$

$$BC = d\sin\theta \qquad (2)$$

From right-angled triangle AB′C, we have

$$\frac{B'C}{d} = \sin\theta$$

$$B'C = d\sin\theta \qquad (3)$$

Putting the values in eq. (i),

Path difference = $(d\sin\theta + d\sin\theta)$

$= 2d\sin\theta$

The two beams will reinforce if this path difference is equal to integral multiple of wavelength λ. Hence, the condition for constructive interference is given by

$$2d\sin\theta = n\lambda \qquad (4)$$

where n = 1, 2, 3 .... and is called order of reflection.

(ii) Explain whether the Young's experiment is an experiment for studying interference or diffraction effects of light.

Ans Young's double slit experiment is basically for studying interference effect of light. However, spreading of light around the edges of the slits also produce some diffraction effects. Therefore, the same experiment can be used to study the diffraction also. It should be noted that the interference effects are more prominent than diffraction effects in Young's experiment.

(iii) How would you manage to get more orders of spectra during a diffraction grating?

Ans As grating equation is given by the relation:

$$d\sin\theta = n\lambda$$

$$\frac{1}{N}\sin\theta = n\lambda$$

$$n = \frac{\sin\theta}{\lambda N}$$

$$\Rightarrow \qquad n \propto \frac{1}{N}$$

This equation shown that orders of spectra can be increased by decreasing the number of lines per cm on the grating.

(iv) Write two differences between angular magnification and resolving power.

Ans Angular magnification simply increases the apparent size of the image of an object when seen through an optical device. It can be made as large as we wish by using lenses of suitable focal lengths.

The resolving power of an optical instrument is its ability to reveal (show) the minor details of an object under examination. It is the minimum angle α_{min} between two point sources that allow the images to be resolved as two distinct spots of light rather than one.

(v) How a single bi-convex lens can be used as a magnifying glass?

Ans Single biconvex lens is used as a magnifying glass (simple microscope) when the object is placed between the lens and its focus. It form a virtual, erect and magnifying image at a distance of 25 cm.

(vi) Derive Charles' law from kinetic theory of gases.

Ans From Kinetic theory of gases

$$V = \frac{2N}{3P} \left\langle \frac{1}{2} mv^2 \right\rangle$$

If pressure is kept constant, then

$$V = \text{Constant} \left\langle \frac{1}{2} mv^2 \right\rangle$$

As $\left\langle \frac{1}{2} mv^2 \right\rangle \propto T$

So, $(V \propto T)$

Thus, volume is directly proportional to absolute temperature of gas provided pressure is kept. This is called Charles' law.

(vii) Justify! Work and heat are similar.

Ans Work and heat are inter-convertible *i.e.*, work can be converted into heat and heat can be converted into work. For example, in steam engine, supplied heat is input and work done by the engine is output.

Consequently, if the heat is taken +ve, then work out should be also taken as +ve quantity.

Sign Conventions:

1. Work done by the system on the surrounding is taken as +ve quantity.
2. Work done on the system by the surrounding is taken negative.
3. Heat supplied to the system is taken positive.
4. Heat released by the system is taken negative.

(viii) Show that: Change in entropy is always positive.

Ans **Entropy:**

It is the measure of disorder of a system. Its symbol is S.

Formula for change of Entropy ΔS.

If heat ΔQ is added to a system at absolute temperature T, then the increase in the state variable called entropy of the system is given by $\Delta S = \frac{\Delta Q}{T}$.

The above formula is for a system undergoing reversible process.

Sign Conventions:

Change in entropy ΔS is positive when heat $+\Delta Q$ is added and negative when heat $-\Delta Q$ is removed from the system.

(ix) What happens to the temperature of the room when an air-conditioner is left running on a table in the middle of the room?

Ans A running air-conditioner, placed on a table in the middle room, rejects the heat through the compressor in the same room. Thus, no change in the room temperature will take place because the heat absorbed from the room is expelled or lost in the same room. Hence, there will be no effect on the temperature of the room.

SECTION-II

NOTE: Attempt any Three (3) questions.

Q.5.(a) Prove that molar specific heat of a gas at constant pressure C_p is greater than molar specific heat at constant volume C_v by an amount equal to universal gas constant R. **(5)**

Ans **Derivation of $C_p - C_v = R$:**

When one mole of a gas is heated at constant pressure, the internal energy increases by the same amount as at constant volume for the same rise in temperature ΔT. Thus,

$$\Delta U = C_v \, \Delta T \qquad (1)$$

Since, the gas expands to keep the pressure constant, so it does work $W = P\,\Delta V$, where ΔV is the increase in volume.

Substituting the values of heat transfer Q_p, internal energy ΔU and the work done W, we get

$$Q = \Delta U + W \qquad (2)$$

So, at constant pressure $Q_p = C_p \Delta T$ (3)

So, put values in eq. (2),

$$C_p \,\Delta T = C_v \,\Delta T + P \Delta V \qquad (4)$$

Using equation for one mole of an ideal gas,

$$PV = RT \qquad (5)$$

At constant pressure P, amount of work done by one mole of a gas due to expansion ΔV caused by the rise in temperature ΔT is given by eq. (5)

$$P\,\Delta V = R\,\Delta T$$

Substituting for $P\,\Delta V$ in eq. (2)

$$C_p \,\Delta T = C_v \,\Delta T + R\,\Delta T$$

or $$C_p = C_v + R$$

or $$C_p - C_v = R \qquad (6)$$

It is obvious from eq. (6) that $C_p - C_v$ by an amount is equal to universal gas constant R.

(b) Suppose, we are told that the acceleration of a particle moving in a circle of radius r with uniform speed v is proportional to some power of r, say r^n, and some power of v, say v^m, determine the powers of r and v. (3)

Ans According to question,

$$a \propto v^m r^n$$

$$a = \text{constant } v^m r^n$$

$$\Rightarrow \quad [a] = \text{constant } [v^m][r^n]$$

$$\Rightarrow \quad [LT^{-2}] = \text{constant } [(LT^{-1})^m][L^n]$$

$$[LT^{-2}] = \text{constant } [L^{m+n} T^{-m}]$$

Comparing the power of L and T,

$$1 = m + n \qquad (1)$$

$$-2 = -m \quad \Rightarrow \quad \boxed{m = 2}$$

Putting the value of m in eq. (1), we get

$$1 = 2 + n$$

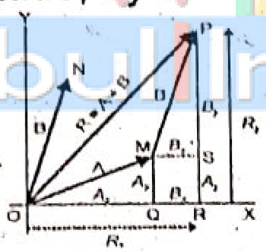
$$1 - 2 = n$$

$$\boxed{-1 = n}$$

Q.6.(a) Explain the method of vector addition by rectangular components. (5)

Ans Vector Addition By Rectangular Components:

Let A and B be two vectors which are represented by two directed lines OM and ON, respectively. The vector B is added to A by the head-to-tail rule of vector addition See (Fig.). Thus, the resultant vector $\vec{R} = \vec{A} + \vec{B}$ is given, in direction and magnitude, by the vector OP.



In the Fig., A_x, B_x and R_x are the x-components of the vectors A, B and R and their magnitudes are given by the lines OQ, MS and OR, respectively, but

$$OR = OQ + QR$$

or $$OR = OQ + MS$$

or $$\vec{R}_x = \vec{A}_x + \vec{B}_x \qquad (1)$$

which means that the sum of the magnitudes of x-components of two vectors which are to be added, is equal to the x-component of the resultant. Similarly, the

sum of the magnitudes of y-components of two vectors is equal to the magnitude of y-component of the resultant, that is,

$$\vec{R}_y = \vec{A}_y + \vec{B}_y \qquad (2)$$

Since, R_x and R_y are the rectangular components of the resultant vector R, hence

$$R = R_x \hat{i} + R_y \hat{j}$$

or $$R = (A_x + B_x)\hat{i} + (A_y + B_y)\hat{j}$$

Magnitude of Resultant Vector:

The magnitude of the resultant vector R is thus given as:

$$R = \sqrt{(A_x + B_x)^2 + (A_y + B_y)^2} \qquad (3)$$

and the direction of the resultant vector is determined from

$$\theta = \tan^{-1}\frac{R_y}{R_x} = \tan^{-1}\frac{(A_y + B_y)}{(A_x + B_x)}$$

and $$\theta = \tan^{-1}\frac{(A_y + B_y)}{(A_x + B_x)} \qquad (4)$$

Similarly, for any number of coplanar vectors A, B, C, we can write

$$R = \sqrt{(A_x + B_x + C_x + ...)^2 + (A_y + B_y + C_y + ...)^2} \qquad (5)$$

and $$\theta = \tan^{-1}\frac{(A_y + B_y + C_y + ...)}{(A_x + B_x + C_x + ...)} \qquad (6)$$

The vector addition by rectangular components consists of the following steps:

(i) Find x and y components of all given vectors.

(ii) Find x-component R_x of the resultant vector by adding the x-components of all the vectors.

(iii) Find y-component R_y of the resultant vector by adding the y-components of all the vectors.

(iv) Find the magnitude of resultant vector R using

$$R = \sqrt{R_x^2 + R_y^2}$$

(v) Find the direction of resultant vector R by using

$$\theta = \tan^{-1}\frac{R_y}{R_x}$$

(b) A football is thrown upward with an angle of 30° with respect to the horizontal. To throw a 40 m pass what must be the initial speed of the ball? (3)

Ans Angle of Projection = $\theta = 30^\circ$

Length of Pass = Range of Projectile = R = 40 m

$g = 9.8\ ms^{-2}$

Initial speed (velocity) of ball = ?

We know that

$$R = \frac{v_1^2 \sin 2\theta}{g}$$

$$40 = \frac{v_1^2 \sin (2 \times 30^\circ)}{9.8}$$

$$40 \times 9.8 = v_1^2 \times \sin 60^\circ$$

$$v_1^2 = \frac{40 \times 9.8}{\sin 60^\circ} = \frac{40 \times 9.8}{0.866}$$

$$= 21.3\ m/s$$

Q.7.(a) Define absolute potential energy. Derive relation for absolute P.E. of a body of mass m. (5)

Ans The absolute gravitational potential energy of an object at a certain position is the work done by the gravitational force in displacing the object from that position to infinity where the force of gravity becomes zero. The relation for the calculation of the work done by the gravitational force or potential energy = mgh, is true only near the surface of the Earth, where the gravitational force is nearly constant. But if the body is displaced through a large distance in space from, let, point 1 to N in the gravitational field, then the gravitational force will not remain constant. Since, it varies inversely to the square of the distance.

In order to overcome this difficulty, we divide the distance between points 1 and N into small steps, each of length Δr so that the value of the force remains constant for each small step. Hence, the total work done can be calculated by adding the work done during all these steps. If r_1 and r_2 are the distances

of points 1 and 2, respectively, from the centre O of the Earth, the work done during the first step *i.e.*, displacing a body from point 1 to point 2 can be calculated as below.

The distance between the centre of this step and the centre of the Earth will be:

$$r = \frac{r_1 + r_2}{2}$$

if $r_2 - r_1 = \Delta r$ then, $r_2 = r_1 + \Delta r$

Hence, $r = \frac{r_1 + r_1 + \Delta r}{2} = r_1 + \frac{\Delta r}{2}$ (i)

The gravitational force F at the centre of this step is

$$F = G\frac{Mm}{r^2} \quad \text{(ii)}$$

where m = mass of an object
M = mass of the Earth
and G = Gravitational constant

(b) A stationary wave is established in a string which is 120 cm long and fixed at both ends. The string vibrates in four segments, at a frequency of 120 Hz. Determine its wavelength and the fundamental frequency. (3)

Ans Length of string = l = 120 cm = 1.2 m

Number of segments = n = 4

Frequency of vibration of string in 4 loops = f_4 = 120 Hz

Wavelength of wave = λ_4 = ?

Fundamental frequency = f_1 = ?

(i) For n-loops in a stretched string fixed at both ends the wavelength is $\lambda_n = \frac{2l}{n}$

$$\therefore \quad \lambda_4 = \frac{2l}{4} = \frac{2 \times 1.2}{4} = 0.6 \text{ m}$$

(ii) Similarly, $f_n = n f_1$

$$f_n = 4 f_1$$

$$120 = 4 f_1$$

$$\Rightarrow \quad f_1 = \frac{120}{4} = 30 \text{ Hz}$$

Q.8.(a) Define SHM. Prove that total energy remains conserved in mass-spring system, oscillating with SHM. (5)

Ans Let us consider a mass m attached to one end of an elastic spring which can move freely on a frictionless horizontal surface. When the mass is displaced towards right through a distance x, the force F at that instant is given by Hooke's law F = kx, where k is a constant known as spring constant. Due to elasticity, spring opposes the applied force which produces the displacement. This opposing force is called restoring force F_r which is equal and opposite to the applied force within elastic limit of the spring. Hence,

$$F_r = -kx \qquad (1)$$

The negative sign indicates that F_r is directed opposite to x. *i.e.,* towards the equilibrium position. Thus, we see that in a system obeying Hooke's law, the restoring force F_r is directly proportional to the displacement x of the system from its equilibrium position and is always directed towards it. When the mass is released, it begins to oscillate about the equilibrium position. The oscillatory motion taking place under the action of such a restoring force is known as simple harmonic motion (SHM). The acceleration 'a' produced in the mass m due to restoring force can be calculated using second law of motion

$$F = ma$$

Then, $-kx = ma$

or $$a = -\frac{k}{m}x \qquad (2)$$

or $a \propto -x$

The acceleration at any instant of a body executing SHM is proportional to displacement and is always directed towards its mean position.

(b) A gramophone record turntable accelerate from rest to an angular velocity of 45.0 rev min^{-1} in 1.60 s. What is its average angular acceleration? (3)

Ans Initial angular velocity = $\omega_i = 0$

Final angular velocity = ω_f = 45 rev/min

$$\omega_f = \frac{45 \times 2\pi \text{ rad}}{60 \text{ sec}} = 4.71 \text{ rad/sec}$$

Time for change in angular velocity = Δt = 1.6 sec

Average angular acceleration = a_{av} = ?

$$\propto_{av} = \frac{\Delta\omega}{\Delta t} = \frac{\omega_f - \omega_i}{\Delta t}$$

$$= \frac{4.71 - 0}{1.60} = 2.94 \text{ rad s}^{-2}$$

Q.9.(a) What is compound microscope? Describe its construction and working also calculate its magnification. (5)

Ans **Microscope:**

Microscope is an instrument which is used to observe the distant or small objects clearly.

Whenever high magnification is required, a compound microscope is used. It consists of two convex lenses, an objective lens of short focal length (f_o) and eye piece of long focal length (fe).

Working:

The object (AB) of height (h) is placed just beyond the principal focus of objective. It produces real magnified and inverted image (A′B′) of height h_1 of the object, within the focal length of eye-piece. It is further magnified by eye piece and the final image A″B″ of height h_2 is formed at near point (d) of the eye.

Magnifying Power:

The angular magnification of compound microscope is given by:

$$M = \frac{\tan\theta_e}{\tan\theta}$$

Where 'θ' is angle subtended by object to unaided eye and θ_e is angle subtended by final image to eye seen through lens.

$$\tan\theta_e = \frac{h_2}{d}$$

$$\tan\theta = \frac{h}{d}$$

By putting these values:

$$M = \frac{\frac{h_2}{d}}{\frac{h}{d}}$$

$$= \frac{h_2}{h}$$

Multiplying and dividing by h_1,

$$M = \frac{h_2}{h} \times \frac{h_1}{h_1}$$

$$= \frac{h_2}{h_1} \times \frac{h_1}{h}$$

$$= \frac{h_1}{h} \times \frac{h_2}{h_1}$$

$$M = M_1 M_2$$

Here,

$$M_1 = \frac{q}{p}$$

$$M_2 = 1 + \frac{d}{f_e}$$

By putting the values:

$$M = \frac{q}{p}\left(1 + \frac{d}{f_e}\right)$$

This is expression for magnifying power of compound microscope.

(b) In a double slit experiment, the second order maximum occurs at $\theta = 0.25^\circ$. The wavelength is 650 nm. Determine the slit separation. (3)

Ans For second order maximum = m = 2

Angle for second order maximum = $\theta = 0.25^\circ$

Wavelength of light = $\lambda = 650\text{ nm} = 650 \times 10^{-9}\text{ m}$

Slit separation = d = ?

We know that equation of maximum is

$$d \sin\theta = m\lambda$$

$$d = \frac{m\lambda}{\sin\theta} = \frac{2 \times 650 \times 10^{-9}}{\sin 0.25^\circ}$$

$$= \frac{1300 \times 10^{-9}}{4.363 \times 10^{-3}}$$

$$= 2.979 \times 10^{-4}\text{ m}$$

$$= 0.2979\text{ mm}$$

$$d = 0.30\text{ mm}$$